The Magic of Science

33rd International Conference on Infrared, Millimeter, and Terahertz Waves

Michael D. Griffin
Administrator
National Aeronautics and Space Administration
15 September 2008

Good morning. I'm really just the warm-up act for Charles Elachi, so I hope that everyone had enough coffee this morning. And, before getting started, I really, really, really want to thank Peter Siegel for giving me an excuse to breathe the fresh air of Los Angeles and escape the hot air in Washington, DC.

We celebrate fifty years of achievement at NASA this year, but I would like to spend some time today talking about our future in space, not our past. To do that, I think we have to let go a little bit, let go of past constraints, and embolden our thinking. My models for that are people you might regard as being a bit unlikely, the great science fiction writers of the past.

One of my favorites, Arthur C. Clarke, offered several priceless observations in connection with predictions about the future. First, he says, when a distinguished but elderly scientist states that something is possible, he is almost certainly right. When he states that something is impossible, he is very probably wrong. Second, the only way to discover the limits of the possible is to venture past them into the impossible. And third, any sufficiently advanced technology is indistinguishable from magic.

Clarke had it right. Advanced technology really is indistinguishable from magic. There's a cute documentary called *God Grew Tired of Us*, in which two young, parentless Sudanese refugees find their way to America, the land of opportunity, and are amazed and awed at the many things that we in our industrialized, information society take for granted – things like running water, electricity, and supermarkets. The movie will help you appreciate the vast difference between our worldview as the most advanced civilization on the planet and the perspective of the majority of the world's population. Our most mundane things are, to them, often magical.

Similarly, almost anyone living a century or so ago would be similarly displaced if suddenly transported into our modern world. Modern jet travel, satellite television with live news from anywhere around the world, IPODs which can download every song ever recorded from the internet, a space station with the volume of a B-747 and a wingspan greater than a football field in orbit around the Earth, and rovers around the planet Mars – these things would be stupefying for most.

Two people to whom they might not would be the great Victorian era science fiction writers, Jules Verne and H. G. Wells. *The Time Machine, The Invisible Man, War of the Worlds, Journey to the Center of the Earth, Twenty Thousand Leagues Under the Sea,* and *Around the World in Eighty Days* sparked the imagination of the public as well as many scientists and engineers over the decades, offering visions for more practical men and women to turn into reality. Victorian science fiction writers like Wells and Verne captured the imagination of the public with fanciful ideas which were seemingly within our grasp. Even more prophetically, they also cautioned against the darker societal consequences of technological capabilities when taken to the extreme.

At a quite fundamental level, NASA's achievements over the past fifty years are a product of such bold visions, and we must acknowledge and respect the role that such playful, whimsical thinking has in inspiring human ingenuity. As Thomas Edison famously said, "Genius is one percent inspiration, and ninety-nine percent perspiration." But that one percent is what makes the innate quality of genius so magical. We dismiss the creative thinking of science fiction at our peril, because the scientific method alone, with its paradigm of logical inference, deduction, and hypothesis testing, is insufficient to account for the human advances we have all seen and lived. It is the unexpected inspiration, the epiphany, which is the source of the magic in science and technology. The down-and-dirty accounts of scientific discovery or engineering breakthroughs, like James Watson's *The Double Helix* or Tracy Kidder's *The Soul of a New Machine*, make this abundantly clear.

But even in the ineffable realm of human creativity, there are different degrees of magic. Many of the things I mentioned earlier – airplanes, rockets, and space stations, might not be beyond imagination to a Victorian observer. After all, rockets had been known to the Chinese for many centuries, da Vinci sketched concepts for powered aircraft, and it was Isaac Newton who articulated the concept of an Earth satellite in his *Principia*. Many of the more grossly spectacular developments of the last century could have been, or were, envisioned by our forebears.

But there is one technology, ubiquitous in everyday life today, that would in fact seem truly magical to even the most forward thinking innovators of a century or more ago, and that is the technology of wireless communication, the bending of "Hertzian waves" to our will.

Wireless communication has redefined and revolutionized human society over the past century, changing the way we work, play, and live. The general public has no idea how radio and television, satellite communication and GPS navigation, TV remotes and Bluetooth, cell phones and wi-fi, actually work. They do not understand even the most basic principles of electromagnetic communication in any form; they merely know that they cannot imagine their modern-day lives without it. Among engineers, the joke when it comes to radio communications is that “it’s FM”, where the M stands for “magic”. But, in my opinion, it is communications technology that has been most responsible for creating the society in which we live today, that has enabled us to communicate around the world, and across our solar system to other worlds, seamlessly and, yes, magically.

And so for a group like this, in the spirit of Sir Arthur’s remarks, I thought it appropriate to discuss how NASA’s space communications architecture will migrate from our current approach to a technology so advanced that it will yield truly magical results. My hope is that my thoughts will motivate the scientists and engineers of JPL, Caltech, and others across the country to help turn it into reality.

NASA’s Deep Space Network, operated by the Jet Propulsion Laboratory, was originally built to support not only the Apollo lunar program, but also our robotic planetary spacecraft. I highly recommend a charming movie called *The Dish*, which tells the story of the men and women at a DSN site on a remote sheep ranch in the rural town of Parkes, near Canberra, Australia. The quirky characters portrayed in the movie, and who staffed the massive 70 meter DSN antenna, played a critical role in relaying the first grainy images of Neil Armstrong setting foot on another world, while everyone on our world held a collective breath. That was a truly magical moment – the first footprint on another world. We will celebrate its 40th anniversary next year. It will be an opportunity to take the measure of our stature today in the exploration of space, while we also highly resolve to return to that world, this time to stay.

So, how are we going to communicate the magical moment when we do return to the moon? What systems do we need to build? If the truth be told, the Deep Space Network is fifty years *old*, not fifty years young, and it is showing its age. So, we have spent some time over the past few years to define a new communications architecture for future human spaceflight missions and Earth and space science programs. We want an integrated, scalable communications network offering exponentially higher data rates.

As we have defined the requirements for our *Constellation* systems with the *Orion* crew exploration vehicle and *Ares* rockets to transport astronauts to low Earth orbit and the moon, as well as the *Altair* lunar lander, we now have a better grasp on what our communications and navigation needs are around the moon. We must think beyond the basic requirements, and must build an infrastructure that can handle sustainable lunar operations while supporting the International Space Station and enabling even greater science return from an armada of robotic spacecraft over the next fifty years. It will be no mean feat. We should not build simply to meet minimal requirements, but to enable qualitatively new capabilities.

As a temporarily non-practicing space system engineer, I often say that no amount of brilliant engineering can save a bad concept. Thus, we took some time to get the concept of operations, requirements, and management structure for our planned communications architecture right from the beginning. It is better to start slowly and get it right than to re-do the plan in middle of the endeavor. "Never time to do it right but always time to do it over" is not an engineering truism for nothing.

First, over the past few years we consolidated the management and budget for our space communications and navigation activities into an agency-level governance structure in order to avoid sub-optimizing the requirements, capabilities, and contract management needed in space communications, while also managing the total cost of our integrated efforts. We used this approach in the old NASA “Code O”, and I believe it was a mistake to get rid of it. We’ve re-established it within our Space Operations Mission Directorate.

We have centralized the management and systems engineering for our previously separate Near Earth Network, Space Network, and the aging Deep Space Network. This is a management challenge which will require hands-on leadership to turn our plans for space communications into reality. With our current budget, we can afford to operate and maintain the aging DSN or we can afford to build a new, integrated communications network. We cannot afford both. Thus, we must be more efficient with automation, commonality, and interoperability between the various communications networks, including those of our international partners, so that we invest the savings in building future capabilities.

It will not be easy. It will *not* be easy. It will require compromise and sacrifices, looking beyond entrenched interested and established ways of doing business in the interest of the greater good. But the end result will allow us to afford the magic.

While the implementation of our architecture will require the ninety-nine percent perspiration of which Edison spoke, the one-percent inspiration will give us the exponentially higher data rates we seek. This will be achieved by shifting our operating frequencies a lot higher – to the optical range of the spectrum. The magic here is the scientific return and the high definition video enabled by means of laser communications. Rather than returning grainy images like those from the first moon landing, we will be able to stream high-definition video upon our return.

With optical communications technology, we will leverage the work of the National Reconnaissance Office on their *GeoLITE* technology demonstration to develop a medium-size optical payload and pathfinder data relay satellite for our missions around the Earth's moon, and other science missions. This pathfinder will be critical in determining whether operational Earth-moon optical communications should be done with direct-to-ground optical receivers, or through an Earth-orbiting relay satellite.

Over the coming years, we also hope to phase out the aging 70 meter DSN antennas in favor of more numerous, but smaller, antennas operating in Ka-band, depending on our progress in developing phased array technology for the forward link.

Interoperability will be a key feature of this space communications architecture. Plans are underway for a meeting of minds this December in Geneva, Switzerland, with the world's space agencies. As part of the Global Exploration Strategy which Shana Dale spearheaded, it is my sincere hope that we can reach consensus on a common internetwork approach, building off the internationally-accepted standards developed by the Consultative Committee of Space Data System. Hundreds of space missions use communications protocols developed by the CCSDS, including the JPL-developed Mars rovers that are, as we sit here, relaying data back to Earth via both U.S. and European spacecraft in orbit around Mars. We need to establish the foundation for new international missions to the moon, Mars, and beyond. To this end, Ed Weiler's science team is identifying new spacecraft missions currently in formulation which can demonstrate the capabilities of optical communication.

As we return to the moon and begin to build a permanent human presence there, just as we have done onboard the International Space Station, interoperability and commonality with our international partners will be key to sustaining the journey. That is why we are building our *Constellation* systems to SI standards wherever possible, and why establishing communications standards and protocols early is so important.

It is eminently worth the effort. I believe that spaceflight in all its forms is the grandest expression of human imagination we have yet experienced. I also believe that it is the most demanding of human endeavors. It is not for the weak or timid; it requires bravery and perseverance to go “where no man has gone before”. But if we can indeed persevere, the result will be a world even more magical than the one that our grandparents imagined, for us.

Thank you.